Red tide mortality on gag grouper 1980-2009

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Red Tide Mortality on Gag grouper 1980-2009

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Introduction

We present in this working paper a draft estimate of natural mortality on gag grouper caused by *Karenia brevis* blooms on the West Florida Shelf. Estimates are made using an Ecopath with Ecosim ecosystem model (Christensen and Pauly 1992, Walters et al. 1997, Pauly et al. 2000). We force mortality caused by red tides across a realistic range of species, using a forcing pattern developed from a combination of two data sources: *K. brevis* cell counts (FWRI, 2013) and a composite red tide index including reflectance and other features (Walters, unpublished data). Thus, red tides affect not only gag grouper, but a full suite of predator and prey species that may indirectly influence the productivity and reproductive success of gag. Nutrients from killed animals (gag and other fish and invertebrate species) are liberated and re-inputted into the ecosystem, so indirect bottom-up influences by the planktonic assemblage are considered.

The Southeast Data, Assessment, and Review (SEDAR) process, which relies on single-species methods, can be made more robust to ecosystem considerations through inclusion of ecosystem-based approaches and derived data. Red tide mortality makes up a component of natural mortality, which is best represented when the ecosystem as a whole is considered. These episodic bloom events, which may be severe and impact a wide range of species and age classes, will affect stock dynamics of managed species through direct and indirect mechanisms. They act synergistically with predation and fishing mortality, and so these influences must be considered simultaneously when reconstructing population dynamics.

Methods

The Ecopath with Ecosim model utilized represents the West Florida Shelf ecosystem. It was first constructed by (Mahmoudi, unpublished data [see Okey et al. 2004 for an application]) and later modified by Gray and Ainsworth (in prep) to incorporate additional exploited and non-exploited species and life stages known to be sensitive to red tides. To incorporate red tide ecosystem effects into the model, an additional (pseudo) fishing fleet is added into the model to provide a red tide mortality driver on adult fish and invertebrates. Biomass caught by this fleet is immediately cycled into the detritus pool, and thus nutrients from killed fish are made available to detritivores and the bacterial decomposition process implicit in Ecosim.

Creating an effort trend

Walter (unpublished data) provides a red tide composite series that is used as a driver of the red tide mortality (entered as an effort driver in Ecosim). The trend only went back as far as 1998. To extend the trend further back to 1980, *K. brevis* cell count data from Fish and Wildlife Research Institute (FWRI) was used. The cell count data was first averaged to yearly values to match the format of the Walter red tide series, and then scaled using a linear relationship to match the mean and variance of the Walter data. The combined data series was then normalized and entered as a relative effort driver for the red tide pseudo-fishery. Effort data (NMFS, 2013) was used to force the effort on all other fleets in the model. This arrangement is a work-around that allows all species, with the exception of gag, to be driven by multiple independent effort series without prescribing the amount of catch or red tide mortality, allowing instead for Ecosim to estimate these. Gag catch was driven separately from other species in the model by forcing fishing mortality, as calculated from SEDAR (2009) catch values, since this was a more accurate way to represent the catch of gag.

The absolute magnitude of effect for the red tide pseudo-fishery (i.e., relative fishing effort) was set by use of an ‘anchor point’ method which grounded one of the years in the series to an observed mortality rate for gag. Based on the assumption that there was an 18% decrease in the gag stock during the severe 2005 bloom, as reported in SEDAR (2009), the effort trend previously established was scaled to elicit a 15% red tide mortality rate on gag ($M_{RT} = 0.15\ yr^{-1}$) in 2005, which was the year with the largest red tide impact according to the Walter data set. The effect was applied to the adult stanza only, which includes ages 2+ in the model. This process was repeated with an assumption of 10% and 20% gag mortality in 2005 to provide an upper and lower bound for the derived mortality trend. Effort for other years was set relative to this 2005 anchor point. The relative impact of red tides across other species was set according to proportions of fish found dead in the FWRI fish kill database (FWRI, 2013).

Results and discussion

The red tide mortality trend reported in Figure 1 is on the order of 0.02 to 0.15 yr^{-1}, with increasing variability towards the end of the simulation. The overall scale of the red tide mortality trend relative to predation mortality and fishing mortality for gag is substantial (Figure 2), exceeding the sum of predation mortality from all predators combined. Low predation on adult gag means their natural mortality trend closely reflects the red tide mortality trend, suggesting that composite series like Walter’s may be usable as a relative index of red tide mortality in future assessments. Red tide mortality affects many of gag’s competitors as well, thus higher consumption rates in gag under stress from red tides occurs probably from a combination of prey release and a reduced mean age of gag (Figure 3). This suggests that red tides potentially lead to increased productivity of gag (as younger fish have higher production rates than older fish). Although the mean level of mortality may be accurate (having been set using the anchor point method), no attempt was made to scale the variability of the trend. Native data values from Walter’s data set were used (and FWRI cell count data was scaled to match). As a result, the variability of the predicted red tide mortality series may be low: the lowest annual mortality rate from red tides (occurring in 1998, 0.0159 yr^{-1} under the 15% anchor point) is approximately 1/10 of the highest mortality rate (occurring in 2005, 0.146 yr^{-1}) (Table 1). This level of variability may be appropriate at annually-averaged intervals; however, future work will confirm this result by comparing predicted mortality rates against the FWRI fish kill record. Note also that this preliminary assessment assumes a linear functional response between *K. brevis* cell counts and fish/invertebrate mortality, and assumes the mortality occurs in adult age classes. Future revisions will consider more sophisticated functional responses (such as stepped responses, saturating and exponential), will expand red tide effects to younger age classes, and will include Monte Carlo sensitivity analysis to provide a maximum likelihood estimate for M_{RT} per year with associated confidence intervals. Future work will also compare the inputted red tide series (effort driver for the pseudo-fishery) against the outputted mortality trend to gauge the importance of food-web interactions in this assessment.

This article should be viewed as a proof-of-concept for developing a red-tide mortality series that incorporates ecosystem effects. An article is in preparation for peer review that will include refinements.

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Table 1. Natural mortality as a result of red tides (M_{RT}) on gag grouper. 10%, 15% and 20% anchor points have been used to scale the absolute effect of red tides in EwE for the year 2005 (gray cells).

Year	10%	15%	20%
1980	0.02606	0.04341	0.06079
1981	0.01999	0.03331	0.04664
1982	0.04001	0.06666	0.09335
1983	0.02644	0.04405	0.06169
1984	0.02205	0.03673	0.05143
1985	0.02178	0.03628	0.05081
1986	0.03053	0.05085	0.07122
1987	0.02883	0.04803	0.06727
1988	0.02090	0.03482	0.04876
1989	0.02012	0.03352	0.04694
1990	0.01988	0.03312	0.04638
1991	0.02647	0.04409	0.06174
1992	0.04294	0.07154	0.10019
1993	0.01963	0.03270	0.04579
1994	0.08016	0.13354	0.18700
1995	0.05742	0.09566	0.13396
1996	0.07027	0.11707	0.16395
1997	0.02174	0.03622	0.05072
1998	0.00953	0.01587	0.02223
1999	0.04001	0.06666	0.09335
2000	0.02230	0.03714	0.05202
2001	0.03336	0.05558	0.07783
2002	0.03642	0.06067	0.08497
2003	0.03530	0.05881	0.08235
2004	0.02912	0.04851	0.06794
2005	0.08789	0.14642	0.20504
2006	0.03462	0.05768	0.08078
2007	0.02691	0.04483	0.06278
2008	0.03410	0.05681	0.07955
2009	0.01652	0.02753	0.03855

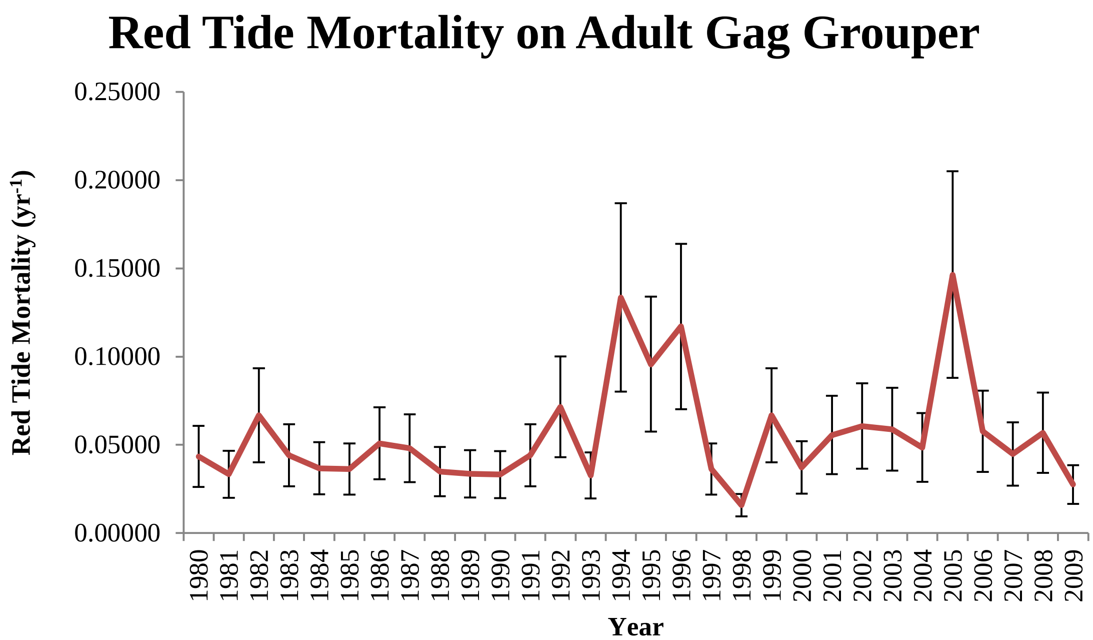

Figure 1. Projection results from red tide model of natural mortality as a result of red tides on gag grouper. The red line represents a 15% anchor point trend. Lower and upper error bars were created by assuming a maximum mortality of 10 and 20%, respectively.

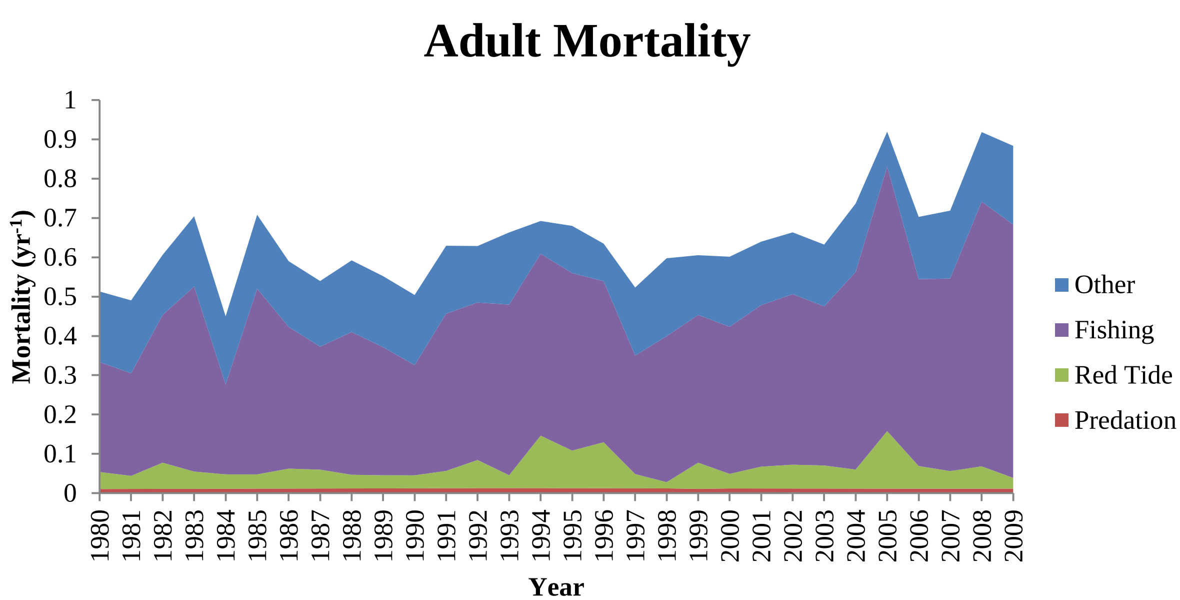

Figure 2. Stacked results to compare all components of gag mortality (yr^{-1}), including fishing, red tide and predation mortalities.

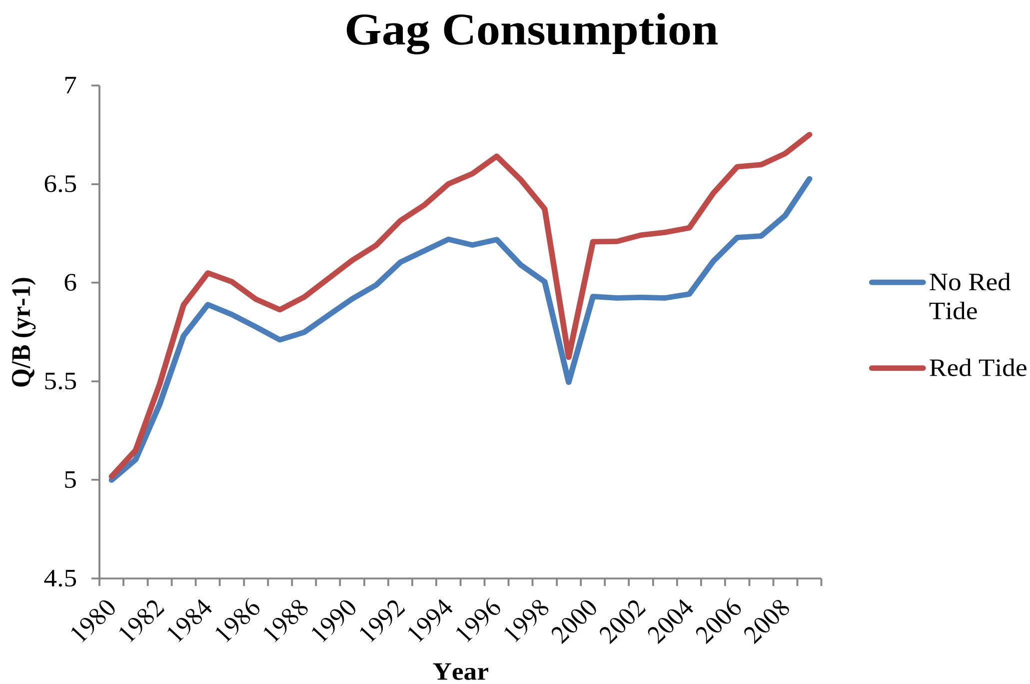

Figure 3. Comparison of gag consumption rates with and without red tide mortality. The red line shows a higher consumption rate when red tide mortality is included, suggesting higher prey availability and potentially higher productivity of gag. The blue line shows the consumption rate by gag when there is no red tide mortality.